Research Plan

On

"Efficiency and Process Optimization in a Sugar Plant: A Case Study"

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1. *Introduction*

With an increasing awareness of the environmental impacts and practical limitations associated with the traditional fossil energy carriers, many countries aim to increase the efficiency of the processes using energy, while shifting to more sustainable energy sources.(Fabian Bühler, 2016)

Energy analysis is the traditional method of assessing the way energy is used in an operation involving the physical or chemical processing of materials and the transfer and/or conversion of energy. This usually entails performing energy balances, which are based on the First Law of Thermodynamics, and evaluating energy efficiencies.

This balance is employed to determine and reduce waste exergy emissions like heat losses and sometimes to enhance waste and heat recovery. However, an energy balance provides no information on the degradation of energy or resources during a process and does not quantify the usefulness or quality of the various energy and material streams flowing through a system and exiting as products and wastes.

The exergy method of analysis overcomes the limitations of the FLT. The concept of exergy is based on both the FLT and the SLT. Exergy analysis clearly indicates the locations of energy degradation in a process and can therefore lead to improved operation or technology. Exergy analysis can also quantify the quality of heat in a waste stream. A main aim of exergy analysis is to identify meaningful (exergy) efficiencies and the causes and true magnitudes of exergy losses.(Ibrahim Dincer, 2013)

In an exergy analysis, the initial state is specified, and thus it is not a variable. The work output is maximized when the process between two specified states is executed in a reversible manner. Therefore, all the irreversibility are disregarded in determining the work potential. Finally, the system must be in the dead state at the end of the process to maximize the work output. In dead state the system is in thermodynamic equilibrium with the environment. (Yunus A Cengel)

Efficiencies based on exergy, unlike those based on energy, are always measures of the approach to true ideality, and therefore provide more meaningful information when assessing the performance of energy systems. Also, exergy losses clearly identify the locations, causes, and sources of deviations from ideality in a system.(Ibrahim Dincer, 2013)

2. *Literature Review of Previous Work*

Table1 Exergy Analysis in Sugar Production Process

Author	Objective	Methodology	Key Findings
Mustafa Bayrak, Adnan Midilli and Kemal Nurveren, (2003)	Conduct an energy and exergy analyses of sugar production stages in Bor Sugar Plant, Turkey	All calculations were accomplished by employing the first andsecond law of thermodynamics.	• It was found that the exergy loses took place mostly during the processes ofsherbet production. • Suggested that the irreversibility, mostly arising from the finite temperature differences at the sugar production stages, should be reduced to carry out moreefficiently the sugar production process.
H. M. Sahin, A. Acir, T. Altunok, E. Baysaland E. Kocyigit	Analysis of exergy and energy of sugarproduction process in sugar plant	Sugarproduction processes considered as a steady state open thermodynamics system andemployed the energy and exergy analyses, based on the first and second laws ofthermodynamicsusing operationalsystem data	• Lowest values resulted from the degradation of energy quality and irreversibilities during the sub operation of the sugar crystallization process. • The rate of the exergy carried by the raw juice should be increased to improve the exergy efficiency and to reduce the degradation of energy quality • Heat exchangers used in all sugar production steps should be suitable for well insulated devices that allow energy exchange between hot and cold fluids
NecmettinSahin, Erkan Kaplan, Mustafa Bayrak,I. FarukYaka and AfsinGungor, 2015	Exergy analysis of Eregli sugar factory	The process is divided into 4 different units in adetailed way and factory-wide including exergyanalysis.	• The factory systems maintenance, repair and renovation have been recommended.

		Exergy analysis of the processes wasconsidered as continuous-flow open systems and themass.	
T. Tekçin And M. Bayramoglu, 1998	Exergy Loss Minimization Analysis Of SugarProduction Process From Sugar Beet	Two techniques, namely; approximate optimization analysis and structural analysis Is applied to simplify the detailed optimization task.	• Presents preliminary results of a detailed study on the minimization of exergy losses in a beet sugar manufacturing plant. • It is found that approximate optimization analysis and structural analysis may be used consecutively; AOA screens the most significant factors while SA partitions the factors as ones to be used for preliminary sub-optimization of some specific units, and ones to be used for a complete plant optimization.
TolgaTaner andMecitSivrioglu, 2015	To determine the best energy and exergy efficiency with the mass and energy balances according to designparameters for a sugar factory	In this study, the laws of thermodynamics are used for energyand exergy analysis calculations, while heat transfer equations areused for heat calculations of the evaporator.	• An overall assessment of the energy and exergy efficiency calculations is performed and is focused on how they should be.
S. M. Bapat, V. S. Majali and G. Ravindranath, 2012	Exergetic evaluation and comparison of quintuple effectevaporation units in Indian sugar industries	Mass and exergybalance, exergy efficiency, improvement potential (IP),exergy ratios, steam economy (SE)	• Large finite temperature difference can be the reason for least efficient component. • There is a decrease in the useful exergy content due to rise in inlet steam temperature • A rise in inlet steam temperature above 125°C is found to be disadvantageous in terms of energy, exergy and the quality of the end product.

TolgaTanera, MecitSivrioglub, 2017	Techno-economic & cost analysis of a turbine power plant	Exergy and exergoeconomic (thermo economic) analysis is exposedto the fuel product term.	• In this study, it was observed thatmass and energy changed the economic cost results significantly. • Because of the techno-economic analysis, the total energy yield of the turbine plant can be increased through design parametersand scenarios.

Table 2 Exergy analysis of cogeneration power plants

Author	Objective	Methodology	Conclusions
Luciana Faria Saint-Martin Pereira et al, (2013)	The exergetic analysis was employed to evaluate the sugar and alcohol plants performance	The method of exergetic analysis of cogeneration in a sugar and alcohol plant was developed and applied to atypical plant	• The thermodynamics first law alone does not evaluate theperformance correctly. • Many exergy is destroyed in the boiler due the combustion irreversibility, explaining the low exergetic efficiency. To improve the system performancea greater attention must be givemainly to the boiler, andnext, to the turbo-generator turbine
Reynaldo Palacios-Bereche et al (2013)	Exergetic analysis of the integrated first- and second-generation ethanol production from sugarcane	An exergetic analysis of a proposed ethanol production scheme in which a new process e enzymatic hydrolysis of sugarcane bagasse is integrated into the conventional process.	• Conducted an assessment of the exergy and exergetic cost associated with the ethanol production process from sugarcane biomass, including the route of bagasse enzymatic hydrolysis. • In spite of the increase in the exergetic cost of the mainproducts, the global exergetic efficiency is higher for the integrated plant in

			comparison with theconventional plant, reaching 36.6% in the Best Case, compared to28.4% for the Base Case.
ChristofferLythcke-Jorgensen (2014)	An exergyanalysis is carried out for a modelled polygeneration system in which lignocellulose ethanol production based on hydrothermal pre-treatment is integrated in an existing combined heat and power (CHP) plant	A numerical model of a polygeneration system that integrateslignocellulose ethanol production based on IBUS technology inthe Danish CHP unit AVV1 is used in the present study	• The load in the CHP unit only had a minor impact on the standard exergy efficiency of the ethanol facility during integrated operation. • The inclusion of district heating production in the ethanol facility was found to increase the standard exergy efficiency slightly. • The efficiency of integratinglignocellulose ethanol production in CHP plants is highly dependent on operation, and it is therefore suggested that the expectedoperation pattern of such polygene-ration system is taken into account when evaluating the potential performance of the polygene rationsystem.
S.C. Kamate, P.B. Gangavati , 2009	Exergy analysis of a heat-matched bagasse-based cogeneration plant of a typical 2500 tcdsugar factory, using backpressure and extraction condensing steam turbine is presented.	In the analysis, exergy methods in addition to the more conventional energy analyses, are employed to evaluate overall and component efficiencies and to identify and assess the thermodynamic losses.	• At optimal steam inlet conditions of 61 bar and 475°C, the backpressure steam turbine cogeneration plant perform with energy and exergy efficiency of 0.863 and 0.307 and condensing steam turbine plant perform with energy and exergy efficiency of 0.682 and 0.260, respectively. • Boiler is the least efficient component and turbine is the most efficient component of the plant.
Pablo Silva Ortiz, Silvio de Oliveira Jr., 2014	In this work via exergy analysisbiomass pre-treatment methods to prepare LB for bioethanol production using two	Four case studies for the following pre-treatmenttechnologies (A) SE, (B) Organosolv, (C) LHW and (D) SE ± LHW are studied	• High exergy valuesare obtained in all cases of this study (A) 93.2%, (B) 85.4%, (C) 94.1%, and (D) 95.1%, the values of destroyedexergy rate found for the cases

	typical chemicalcompositions of sugarcane bagasse are evaluated		analysed using the raw material 2 are high compared to the input bagasseexergy rate, (A) 7.2%, (B) 24.8%, (C) 6.0%, and (D) 5.5%, highlighting the relevance of such processes in theoverall exergy efficiency of second-generation bioethanol production routes.
J. Raghu Ram, Rangan Banerjee, 2003	Energy and cogeneration targeting for a sugar factory	An energybalance has been carried out for an actual 5000 TCD plant and a Sankey diagram is drawn. A pinchanalysis is done for the sugar factory	• Modified evaporator designs are proposed as it has been found that the existing plant is notoptimum with regard to the surface area of the evaporators and the amount of steam being consumed. • Exergy losses can be reduced by48% of its original value if the existing quadruple effect is modified to a quintuple effect.
Luis E. et al 2013	Energy and exergy analysis of a sugar cane bagasse gasifier integrated toa solid oxide fuel cell based on a quasi-equilibrium approach	Develop a comprehensive mathematical model of abagasse gasification unit integrated with a solid oxide fuel cell, for predicting the system performance usingthe energy and exergy criteria.	• The quasi-equilibrium approach is discussed based on the experimental data from a pilot bubbling gasifier for two biomasssources: sugar cane bagasse and rice husk.

3. *Research Gap*

1. In the future other product might be obtained considering different energy conversion routes (Cellulosic ethanol, chemicals) and/or further processing other by products such as stillage and trash to generate more electricity and improve the recycle of nutrients in the crop. Hence the sugarcane industry is a very suitable platform for the development and continuous improvements
2. Energy and exergy analysis of sugar production processes has been studied by some researchers but not for Indian Sugar Plant.
3. In the literature, there is limited information and research on the energy and exergy analysis of sugar production processes.
4. The increasing demand of energy has been a prime source of motivation for the development of alternate fuels.
5. Pressmud, Bagasse and Molasses are industrial waste available from the sugar mills. For every 100 tonnes of sugarcane crushed about 3 tons of Pressmud cake is left behind as by-product. In existing system, the steam is generated in the low-pressure boilers by burning all the bagasse generated. Thus there is need for further investigation in this era.

4. *Overview of Project*

The objectives of the proposed research work are as follows:

1. To develop process models of process technologies, specifically combustion and pyrolysis, to convert sugar mill biomass (bagasse, molasses and Pressmud) into useful energy/energy products,
2. To make the comparison in terms of efficiency, environment sustainability and capability of meeting the energy demands of the sugar mill.
3. To analyse of exergy and energy of sugar production process in sugar plant as the confluence of energy, environment, and sustainable development
4. To carry out exergetic life cycle assessment (ExLCA) to evaluate the sugar plants performance.
5. To identifying the causes, locations, and magnitudes of process inefficiencies.

6. *Research Progress*

Progress of Research	Tasks for Next Six Months
• A Comprehensive Literature Review has been done and Published research paper entitled " A review on thermodynamics analysis and waste energy utilization in cement industry", in TJPRC a SCOPUS Index journal • A Relative study of Sugarcane Bagasse gasification and Direct Combustion has been done and published paper in International Journal of Applied Engineering Research (IJAER) a SCOPUS Index journal and paper entitled "A Comparative study of Sugarcane Bagasse gasification and Direct Combustion"	• An analysis will be carry out specifically combustion and pyrolysis, to convert molasses and Pressmud into useful energy/energy products, and to compare in terms of efficiency, environment sustainability and capability of meeting the energy demands of the sugar mill. • Exergy and exergetic life cycle assessment analysis sugar production process in sugar plant as the confluence of energy, environment, and sustainable development

7. Issues

No difficulties have occurred in the reporting period.

8. Changes

Not Any

9. Complete Research plan

The following steps will be followed to accomplish the work:

Exergy and Energy Analysis:

A simple procedure for performing energy and exergy analyses involves the following steps:

A. The sugar manufacturing process will be subdivided under consideration into as many sections as desired, depending on the depth of detail and understanding desired from the analysis.

B. Conventional mass and energy balances will be performed on the process, and all basic quantities will be determined (e.g., work, heat) and properties (e.g., temperature, pressure).

C. Based on the nature of the process, the acceptable degree of analysis complexity and accuracy, and the questions for which answers will be sought, while selecting a reference-environment model.

D. Evaluation of energy and exergy values, relative to the selected reference-environment model.

E. Perform exergy balances, including the determination of exergy consumptions.

F. Select efficiency definitions, depending on the measures of merit desired, and evaluate values for the efficiencies.

G. Interpretation of results, and drawing of appropriate conclusions and recommendations, relating to such issues as design changes, retrofit plant modifications, etc

Life Cycle Assessment

For the life cycle assessment, the steps split into five stages that include:

1. Planning: Includes Statement of objectives, Definition of the product and its alternatives, Choice of system boundaries, Choice of environmental parameters, Choice of aggregation and evaluation method and Strategy for data collection

2. Screening: Includes preliminary execution of LCA and adjustment of plan.

3. Data collection and treatment: Includes measurements, interviews, literature search, theoretical calculations, database search, qualified guessing and also computation of the inventory table.

4. Evaluation: Includes classification of inventory table into impact categories, aggregation within category, normalization and weighting of different categories.

5. Improvement assessment: Includes sensitivity analysis and improvement priority and feasibility assessment

Develop process models of process technologies, specifically combustion and pyrolysis, to convert sugar mill biomass (bagasse, molasses and Pressmud) into useful energy/energy products

The following steps will be followed

1. Sampling of waste from sugar mill

2. Characterization of sugar industrial waste using Proximate, Ultimate analysis and also some another tests.

3. Process Modelling using Aspen plus/ ANSYS as software tool.

4. Comparison in terms of efficiency and capability of meeting the energy demands of the sugar mill and extra power that can be generate.